LARS Contract Report 012080

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FOREST RESOURCE INFORMATION SYSTEM

Phase III Quarterly Report

for the period

1 October 1979 to 31 December 1979

Prepared for

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

Johnson Space Center
Earth Observations Division
Houston, Texas 77058

Contract: NAS 9-15325
Technical Monitor: R. E. Joosten/SF5

Submitted by:

The Laboratory for Applications of Remote Sensing
Purdue University
West Lafayette, Indiana 47906

Principal Investigator: R. P. Mroczynski

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16. Abstract

This report covers the third quarter of the fifteen-month System Transfer Phase of the Forest Resource Information System Application Pilot Test. The principal Activities during this quarter revolved around transferring software systems, and training St. Regis staff in Landsat analysis procedures. Results of an Applications Pilot Test Project which involved the preparation and classification of two Landsat scenes and the production of a resulting change map are also reported this period.

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FRIS PROJECT OVERVIEW

The Forest Resource Information System Project (FRIS) is a cooperative effort between the National Aeronautics and Space Administration (NASA) and St. Regis Paper Co. (STR). Purdue University's Laboratory for Applications of Remote Sensing (LARS), under contract to NASA, will supply technical support to the project.

FRIS is an Application Pilot Test (APT) Project funded by NASA. The project is interdisciplinary in nature involving expertise from both the public and private sectors. FRIS also represents the first APT to involve a large broad base forest industry (STR) in a cooperative with the government and the academic communities.

Purpose

The goal of FRIS is to demonstrate the feasibility of using computer-aided analysis techniques applied of Landsat Multispectral Scanner Data to broaden and improve the existing STR forest data base, thereby creating the foundation of a dynamic information system. The successful demonstration of this technology during the first half of the project will lead to the establishment by STR of an independently controlled operational forest resource information system in which Landsat data is expected to make a significant contribution. FRIS can be viewed by the user community as a model of NASA's involvement in practical application and effective use of space technology. Additionally, FRIS will serve to demonstrate the capability of Landsat MSS data and machine-assisted analysis technology to private industry by:

- Determining economic potentials,
- Providing visibility and documentation, and

- The ability to provide timely information and thus serve management needs.

The ultimate long term successfulness of FRIS can be measured through future development of remote sensing technology within the forest products industry.

Scope

FRIS is funded as a modular or Phase project with an anticipated duration of three years. The original project concepts were developed in 1973, and a formal project plan was submitted to NASA by STR in 1976. The project officially began in October 1977 after the signing of a cooperative agreement between NASA and STR; and after the compeltion of contractual arrangements with Purdue University.

Organization

The organization of FRIS is depicted in the chart that follows. Since FRIS is a cooperative involving three independent agencies, a steering committee consisting of a project manager from each institution was formed to provide for overall guidance and coordination. Operationally, both STR and LARS have project managers and project staff to insure for the timely completion of activities within the project. The NASA technical coordinator monitors project activities and provides a liaison between the STR and LARS staffs. The solid lines on the chart indicate the flow of management responsibility. The dash lines reflect the technical and scientific inter-changes between operating units.

FRIS Organization

Steering Committee

ASVT Project Manager
NASA Technical Monitor
FRIS Project Manager

Resource and Technology Department/ STR.	NASA Johnson Spacecraft Center	LARS/ Purdue University
Computer Systems		Systems Design
Cartographic Systems		Mapping Unit
Forest Sampling Systems		Classification Unit
Cost Analysis		Cost Unit

1.0 INTRODUCTION

The material appearing in this report is a reflection of the FRIS Project Staff activities for the period 1 October 1979 to 31 December 1979. This time frame encompasses the third quarterly reporting period for Phase III of the Forest Resource Information System (FRIS) Applications Pilot Test (APT). Phase III of FRIS is directed at meeting the overall Project goal:

> To document and transfer remote sensing technology developed throughout the project that will provide St. Regis with an independent operational system, having Landsat data as a significant and viable contributor.

Significant strides were made toward reaching this Project goal during this reporting period. Noteworthy activities that occurred during this quarter are summarized below:

- A terminal connecting LARS to St. Regis National Computer Center was installed.
- LARS staff received training on use of the St. Regis terminal.
- The System Design Committee defined functional specifications for the FRIS configuration.
- Preliminary versions of new software was prepared for testing.
- Results of the applications test initiated the previous quarter were presented to St. Regis.
- A technique designed to predict age of planted pine stands was tested for the Knabb Application Test Area.

The remaining sections of this report describe these activities in

more complete detail. Appendix B contains update timeline charts for all tasks.

Acknowledoements

Inputs for various sections of this report were provided by FRIS staff. The principal investigator is grateful to the following individuals for their contributions:

Section 2.1	Sue Schwingendorf
Section 2.2	Bill Shelley Dave Freeman Cathy Kozlowski
Section 2.3	Chuck Smith Bud Goodrick
Section 2.4	Carol Peterson

2.0 TASK AREA ACTIVITIES

2.1 Technology Transfer Task

A key element in the System Transfer Phase of FRIS is the development of a knowledgable core of St. Regis analysts. Formal short courses, workshops and text material are items which help support this development. However useful these exercised are, they are no substitute for actual analysis experience.

The "hands-on" experience requirement for analyst training was the motivation for supporting a remote terminal link between the Southern Timberlands Divisional office at Jacksonville, FL and LARS. Details regarding this remote terminal configuration and operation can be found in previous FRIS Quarterly Reports. Previous task activities were directly related to supporting this remote terminal link. Therefore, preliminary training and documentation supports the interactive LARSYS analysis capability of the terminal. Operationally, the FRIS Image Processing will be conducted in a batch mode. This change will necessitate modification of the training procedures and documentation to reflect the St. Regis National Computer Center (NCC) operating environment.

In order to accomodate the smooth transition of the technology associated with the change in computer operating environments a decision was made to connect LARS to NCC via a remote terminal link. This link would allow the Technology Transfer staff to develop supplemental training and documentation necessary to execute LARSYS functions through

ROSCOE, St. Regis' interactive echting software.

During this quarter, the equipment for Project staff terminal connection to Dallas was ordered, received and installed. It was previously determined that this terminal conncection would consist of an IBM 3275 CRT terminal for editting and job entry (with the necessary phone line and modem) to be provided by St. Regis, and a Data 100 RJE terminal for receiving printer output (with the equipment required to provide dial-up access to the St. Regis computer), which would be supplied by Purdue/LARS. In October, the following equipment was ordered by Purdue/LARS to allow us to connect the Data 100 terminal at LARS/Flexlab 2 to the St. Regis NCC: a Racal/Milgo MPS48 dial modem, a T-bar digital switch, two cables and a business telephone with a manual DAA.

Also during October, the IBM 3275 CRT terminal arrived. Its telephone line was installed in early November and the modem arrived November 12. By November 16 the terminal, modem and phone line were connected together and working. For greater security, this terminal has been placed in the Purdue/LARS computer room and the LARS computer operators have been given a list of project personnel authorized to use the terminal.

The telephone for the Data 100 terminal connection was installed in mid-November, the dial modem arrived November 29 and was installed December 7. After a few more changes to the modem and the removal of a 4-wire modification in the Data 100 load deck, the Data 100 terminal was able to receive printer output from the St. Regis NCC.

Training Activities

On Monday and Tuesday, October 8 and 9, Al Beecher was at LARS to review his progress on the installation of the LARS Data Reformatting programs on the St. Regis NCC computer. He discussed the LARSYS support routines with Bill Shelley, the reformatting routines with Chuck Smith and the geometric correction programs with Cathy Kozlowski. No major problems are anticipated.

A ROSCOE training session scheduled for November 27 was abbreviated to an informal demonstration by Al Beecher of sign on and editting procedures, due to the delay in the installation of the Data 100 connection.

The ROSCOE training session was rescheduled for December 19 at LARS. Bob Lynn presented the material to ten project personnel at LARS and assisted them in hands-on sessions at the IBM 3275 CRT terminal.

2.2 System Transfer Tasks

2.2.1 System Design Committee

During the third quarter of Phase III the System Design Committee met several times to formalize FRIS specifications. The list of functional specifications that were developed by the committee appear in Table 2.2.1 . Three vendors of data base systems were asked to demonstrate their systems capabilities and bid on the system installation in Jacksonville, FL.

Demonstration materials were prepared by FRIS staff. Each vendor

Table 2.2.1 Functional Specifications for Evaluation of FRIS System Design Alternatives

I. Graphic Data Capability
   - A. Input
   - B. Analysis
   - C. Update
   - D. Output

II. Tabular Data Capability
   - A. Input
   - B. Analysis
   - C. Update
   - D. Output

III. Image Data Capability
   - A. Conversion from vector to grid
   - B. Conversion from grid to vector

IV. Other
   - A. Hardware
     1. Configuration
     2. Deliverability
     3. Support
     4. Data Communications
   - B. Software
     1. Availability/cost of source
     2. Support
     3. Transportability
   - C. Implementation
     1. Cost
     2. Time
   - D. Vendor Profile
     1. Customer base
     2. Customer service
     3. Expertise in forest based applications
     4. Vendor stability

V. Overall Cost

Table 2.2.2 FRIS data base manipulation requirements

1. Produce a plot of the digitized data, containing the AU (Administrative Unit) and OA (Operating Area) boundaries for all four of the AU's.
2. The fourth file of the tape contains some extraneous points, produce a clean plot demonstrating the editting capabilities.
3. Convert the Landsat classification data from grid to vector format.
4. Produce a plot of each layer of information
   a. AU boundaries
   b. OA boundaries
   c. Landsat classification
5. Associate attribute data with each layer of information
   a. for the AU boundaries layer, the attributes would consist of the AU numbers (264, 267, 268, and 271).
   b. for the OA boundaries layer, the attributes of interest would be the OA numbers, the forest type, and the age of the stand (this information may be found on the sheets describing each individual AU).
   c. for the classification data, this would be the names of the classes taken from the classification results tape.
6. Produce an overlay of the three layers of information.
7. Graphically represent where the Landsat classification and the map are in disagreement for a cover type. What we have in mind is a map depicting areas that would satisfy such Boolean combinations as: NONSTOCK (from the Landsat classification) .AND. .NOT. (forest types 9 .OR. 92 (from the map)).
8. It would also be desirous to have maps of areas based upon the attributes of the OA's (e.g., Forest types 2, 11, and 21 which are greater than 15 years old).
9. Demonstrate the capability to apply transformations to the vector data sets (e.g., for rotation and scale).

received the following data:

1. Map of AU's (Administrative Units) 264,267,268, and 271.
2. Documentation of map contents.
3. Tape containing digitized map information, as digitized by IOM-TOWELL.
4. Documentation received from IOM-TOWELL.
5. Tape containing Landsat classification data.
6. Documentation of tape contents.

The requirements for manipulation of these data sets are defined in Table 2.2.2 . Each vendor was asked to demonstrate their capability in these nine areas, or to indicate how they would meet these requirements if the capability did not exist. In addition to demonstrating their systems capabilities, vendors were asked to provide a firm bid for installation of the System in Jacksonville.

During the final System Design Committee meeting in Dallas, Texas in early December, vendors capabilities were evaluated. The committee was primarily concerned with the vendors capability of meeting the FRIS system requirements. Bid information was used by St. Regis staff to prepare financial evaluation for St. Regis management.

2.2.2 Preprocessing Transfer

LARSYS preprocessing software development is the task which resulted from a number of FRIS system design meetings beginning in July of 1978. As of July 1979, the FRIS system design had progressed to a point that the LARSYS preprocessing and analysis software to be trans-

ferred to the St. Regis has been determined. LARSYS preprocessing software consists of three major processors. The three processors convert digital Landsat data to LARSYS format, perform systematic geometric corrections of Landsat data and register two images of Landsat data. The final task beyond the transfer of software is the documentation of the software.

Reformatting

The first preprocessing system of programs converts digital Landsat data to LARSYS format. The functional specifications for this processor required the conversion of input EDIPS "P" Landsat MSS data received in a band interleaved by line (BIL) format to LARSYS format. "P" format refers to EDIPS format computer compatible tape data requested as CCT-PM or fully processed MSS data with geometric corrections applied and resampled to a map projection. Details of this format may be found in the "Manual on Characteristics of Landsat Computer-Compatible Tapes" published by the EROS Data Center in December 1978.

Preliminary work on the design specifications for the "P" format Landsat data processor began in early March 1979. In particular, the LARS reformatting group determined that a comprehensive design phase would substantially shorten implementation during the programming, debugging, and documentation phases. Work on the design lasted into early July. Every algorithm was defined, program modules specified, and nearly all substantive variables and buffer areas were identified before programming began. The main routine, along with all subroutines

and calling sequences, were thus determined and documented. The program design included accomodation for function specifications which would support both nearly automatic operations in an operational environment as well as multiple options required in a scientific research environment.

Several techniques were utilized to solve this problem. First, the basic approach was top-down structured programming. All routines have a top to bottom flow of control, and top of calling sequences modules were programmed first. As much testing as possible was done after completion of each module and assembly of it with previously completed modules higher in the calling sequence. The second technique was to place a unique or substantive process in a separate module. Modules were allocated based on the structured "English" version of the processing algorithm (Appendix A-1). The question asked by the analyst as he scans this "structured English" program would be what processes must occur for this "sentence" or "group of sentences" to successfully execute. The answer defined the modules to be programmed. Third, the primary programming language was FORTRAN IV utilizing the IBM Level G or H compilers. Som IBM Assembly Language program includes the structured "English" versions of the algorithms used.

In addition, the implementation of the entire EDIPS to LARSYS programming task was PERT charted. This aided in the management of time and resources for the project. Parallel programming efforts could then be spotted as well as known or potential bottlenecks. Finally, to facilitate the control of the program in the most humanly

efficient default mode, only three cards are required to execute the EDIPS processor.

Geometric Correction

The geometric correction processor was the second major system of programs. The geometric correction processors original functional specifications called for maximum correction of geometric distortions of Landsat I data with minimum use of resources. The most important distortions thus were corrected. In particular, the data is assumed to consist of square 80 meter pixels which are rotated to true north, deskewed for the earth's rotation and rescaled for output on a line printer with 8 x 10 aspect. In the context of FRIS pre-EDIPS format Landsat data may be corrected for geometric distortions.

In the current FRIS image preprocessing system, this program may be utilized to rotate Landsat III data to true north and rescale it if necessary. This is especially important considering the number of data sources already in true north orientation. Examples are the St. Regis Administrative Unit maps. Data in the same orientation is far easier to use for the human than data skewed or rotated relative to a given true north reference data set as the forest AU mentioned previously. For example, checkpoints are more readily defined and located as part of the image registration process. Relatively minor updates to the control card reader to incorporate the rotation-only parameter will be required to bring this program to transfer status. Inspection and update of program listings, program abstracts, and user documentation will also be required.

Image Registration

The last major processor is the image registration system. The primary purpose of this system is to register two coincident digital images such as two Landsat digital image data sets. The secondary purpose is to provide for the registration of any known two-dimensional grid to another known or defined two-dimensional grid. An example is the registration of Landsat data to a USGS quad map. The former has a grid X-Y of pixel locations while the latter has a grid of inches horizontally and vertically. Input images are assumed to be in LARSYS format.

The image registration system software consists of three functional sections: 1) the main image registration section, 2) the coincident image cross-correlation section, and 3) the multifit least squares analysis. While such software exists to do part of this task, a revised processor was desirable to achieve a modern supportable software system. The writers of the old system are no longer available and documentation for the program is sparse. The procedure to be followed in this image registration system programming task follows that of the EDIPS processor mentioned above. Once the need for the new processor was established, functional specifications were determined. The overall goal is to produce a maintainable system which is modularized, as well as documented for program contents, programming techniques and user documentation. Furthermore, the latest obtainable registration techniques for reasonable implementation. No attempt will be made to duplicate the Goddard MDP (Master Data Processor). The function of the

system, however, is similar. Two standard registration procedures are being utilized to allow more accurate, cost efficient registrations.

The two implementation procedures are the use of a cubic polynomial for the overall registration and the use of blocking with linear interpolation. The first refers to the cubic polynomial whose coefficients will be derived from the MULTIFIT processor. This processor uses least squares analysis to derive the best affine, bi-quadratic or bi-cubic fits for the checkpoints taken from the respective digital images or known grids as appropriate. With the best equation fit determined, normally a bicubic one, the blocking concept will be utilized to reduce computation time.

The concept of blocking during digital image registration is a moderately complex one. First, the bicubic polynomial for image location is investigated for rates of change and saddle points by solving the first and second derivatives. Utilizing these values one may determine the minimum block size within which a bilinear function accurately approximates the bicubic one. Block size may be thought of as Y lines by Z columns. At least "Z" number of multiple times are eliminated from the calculation of each pixel location within the block. Only the corner pixel locations of each block need to be calculated in full bicubic polynomial mode. The linear interpolation within the block is relatively fast and predictable with far fewer calculations. Should the biquadratic polynomial be the best fit for the data, blocking may still be used. However, the reduction in the location calculation time will not be as great. In the unlikely event that a linear fit will suffice, blocking is not used.

Other features of the registration system include an automated cross correlation processor and two forms of pixel gray level interpolation. First the automated cross-correlation processor is an aid for acquiring checkpoint locations which are selected from two coincident Landsat digital image data sets. This cross-correlation will be accomplished by the implementation of a numerical integration image correlator. Control of where checkpoints are sought may be by line and column intervals and starting and stopping locations. Alternate control may be by a set of arbitrary checkpoints for location after cross-correlation. An appropriate initial transformation will accompany either control method. Should this concept not be practical because of data dependency problems, manual checkpointing methods will be used.

The second feature is a gray level interpolation method. A gray level must be determined for each pixel location in the output grid. The nearest neighbor is the default. The advantage of nearest neighbor interpolation is that no new data values are created. Classification algorithms may use the same statistics before and after registration. Cubic interpolation of pixel gray levels is the alternative. This cubic interpolation algorithm assumes surrounding pixels input to the respective "center" pixel's gray level. The "center" pixel refers to the calculated subpixel location outputed from the registration polynomial. The pixel location is theoretically subpixel and the level of each surrounding pixel to the "center" pixel is determined by which of the sixteen subpixel locations is calculated for the "center" pixel. To facilitate the implementation of this third order Lagrange inter-

polation, "center" pixels locations are calculated to one quarter of a pixel. Coefficients are pre-supplied in a table for each of the sixteen possible "center" pixel locations. The level of calculation is thus restricted to simple addition and multiplication. Cubic interpolation of gray levels smooths the visual look of images. This approach has the potential for portraying slightly more accurate subpixel locations for given features of the scene. Compared to the nearest neighbor interpolation technique, the cubic convalation approach requires more computer-resources.

Preprocessing Documentation

Documentation is the last major effort of the LARSYS preprocessing software implementation. Documentation will consist of three main efforts for each of the three processors previously described. The three types of documentation will be; 1) program listing documentation, 2) program module abstracts, and 3) user documentation. The first form of documentation has been guided by a standars document produced by the reformatting group. These standards expand and clear up details of program listing documentation to be followed in the preprocessing software. Inputs, outputs, and major variables and arrays are detailed at the top of each program listing under this standard. In addition, processing procedures are clearly explained through comments in the listing. In essence, a new programmer should be able to read the comments within the listing and know what algorithm the code is implementing.

Programming abstracts are the second form of documentation. These follow the LARSYS standard manual. This form of documentation normally will be used with the program listing for maximum communication to the programmer.

Finally, user documentation is to be generated. The user document should describe what a processor is used for as well as how to use it. Sample control card sets will be included along with explanations of what each set does. It will be coordinated to the extent that a minimum amount of information will be included regarding where the processor is utilized in the preprocessing of digital images as Landsat data.

Documentation is a key to the technology transfer of the LARS image processing/analysis system totally known as LARSYS. Good documentation although expensive, is necessary to inform the programmer and user. The programs will be more maintainable by less readily knowledgeable programming professionals. Over the long term this potentially means less total time and expense. To the creator of the documentation, the effort means a more thorough knowledge of just what he or she has transferred to a fellow programmer in another organization.

This total LARSYS preprocessing effort has been and continues to be a considerable one. Every resource is being utilized to maintain an orderly and effective transfer of the LARSYS preprocessing software in a timely fashion. To this point, the schedule of events has been on target. We intend to keep it that way through its completion.

2.2.3 LARSYS Transfer

LARSYS as it currently exists at Purdue University's Laboratory for Applications of Remote Sensing (LARS), consists of 4[illegible] processing functions contained in 377 FORTRAN routines and 49 IBM ASSEMBLER routines. LARSYS is not just an integrated set of computer programs designed for the analysis of remote sensing data. It is an entire approach to the conversion of remote sensing data into information useful for monitoring and inventorying earth resources. Results of the Demonstration Phase of FRIS document the utility of the approach to industrial forest management in the southeast.

The System Transfer Phase of FRIS therefore not only deals with the implementation of the LARSYS software, but also the transfer of the concept. The FRIS image processing subsystem will be comprised of a subset of the LARSYS ver. 3.1 software package which is currently available through COSMIC. In addition select developmental and experimental routines, some of which were developed specifically for FRIS, will also be transferred.

As part of this transfer activity, source tapes, program listings, users' manuals, system manual, control card references, and program abstracts were provided to St. Regis for 23 image processing processors. The following is a brief description of these processors:

PICTUREPRINT - histograms and displays data in picture form on a line printer for each channel selected.

CLUSTER - using reflectance values from selected channels, groups data into classes and displays the results on a line printer.

STATISTICS - calculates transformed divergence between all class pairs and performs these calculations for every set of channels requested.

CLASSIFYPOINTS - assigns each pixel in the data to a class, using either the maximum likelihood algorithm or minimum distance rule. The results are written to tape or disk.

PRINTRESULTS - using the classification results located on tape or disk, prints a map and tabulates the number of pixels classified into each class.

IDPRINT - prints most of the information contained in the MSS data header record.

DUPLICATERUN - duplicates a data run from tape to tape, and optionally allows arithmetic expressions to be applied to the data.

COPYRESULTS - copies classification results from disk or tape to another tape.

LISTRESULTS - prints information located in the header records of the classification results.

PUNCHSTATISTICS - punches a copy of the statistics deck located on a classification results tape.

LINEGRAPH - graphs a line of MSS data on a line printer.

COLUMNGRAPH - graphs a column of MSS data on a line printer.

HISTOGRAM - histograms data and produces a deck of the histogram information.

GRAPHHISTOGRAM - on a line printer, displays the histogram produced by PICTUREPRINT or HISTOGRAM processors.

ECHO - extracts and classifies homogeneous objects as if they were single pixels.

MERGESTATISTICS - combines more than one statistics deck into a single deck.

BROWSE - searches the LARSYS runtable and prints the list of MSS data runs which satisfy the user's request.

RATIO - using the mean vectors of classes in a statistics deck, calculates and prints the ratio of the values for the specified channels and the sum for each class.

GDATA - histograms and displays data in picture form on a printer/plotter for each channel selected.

GRESULTS - using the classification results, prints a map on a printer/plotter and tabulates the results.

BIPLOT - produces a bispectral plot of classes contained in a statistics deck.

CHANGE - compares two classifications results over the same area for purposes of change detection.

The above processors represent 42,000 lines of FORTRAN, 5500 lines of Assembler, and 1500 lines of CMS EXEC language. The conversion effort for this software consists of 1) converting from FORTRAN G to FORTRAN H, 2) removing operating system dependencies from the Assembler, and 3) converting the CMS EXEC language into JCL. During this past quarter, the first two of these were accomplished, although the software will not be able to be tested until the third is completed.

2.2.4 Programming Additions

During this quarter, the initial coding and debugging of a new LARSYS processor was completed. This processor implements a polling algorithm which scans a classification results file a cell (or group of points) at a time, and assigns the majority class number from that cell to all points in the cell. The purpose of this is to eliminate isolated points from the classification map in order to provide an output product that matches the naming conventions of the user, in this case the St. Regis Paper Company. This processor is currently being tested and enhanced. Documentation and sample maps will be included in the next quarterly report.

2.3 Applications Test

In mid-July 1979 the FRIS APT Manager requested that the project staff undertake an operational test of the remote sensing technology. Specifically, the project staff was to provide a change classification of a tract of land in Baker County, Florida (figure 2.3.1) that St. Regis had recently acquired.

The new acquisition, the Knabb Tract, encompasses approximately 40,000 acres of land and is ecologically similar to the Fargo test site. St. Regis staff were of the opinion that the timber removals had been extensive in recent years. Furthermore, they felt that removals were especially extensive since 1977.

The application test was designed to address the feasibility of using Landsat classified data to:

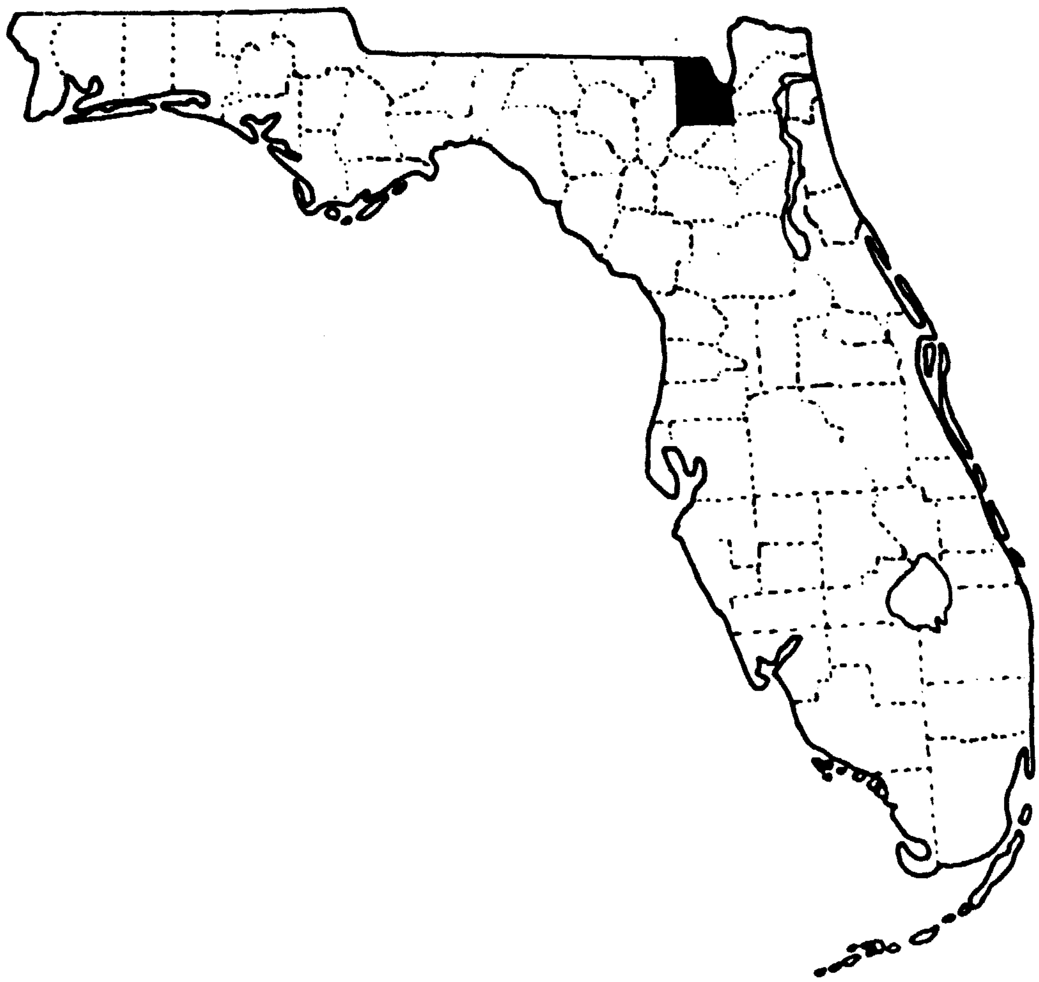

Figure 2.3.1 Location of Baker County, Florida and the Knabb Tract Application Test Site.

1) Evaluate the areal extent of the standing timber resource, from 1979 data, and

2) determine the change in standing timber that was detected by Landsat that occurred between 1977 and 1979.

Our goal was to meet these objectives and to provide classification results by 1 November 1979. Timing was an important criteria to this application test because if the data could not be:

- o Acquired
- o Preprocessed
- o Classified, and
- o Final products available

by the deadline, than the timeliness of the technology would be seriously questioned. In November the window for photographic data collection opens, and this tract was flown. If Landsat information was not available by the time the photography was collected and interpreted than the utility of Landsat as an industrial forest management tool will be seriously questioned.

Two critical elements to the successful completion of this applications test were the data preprocessing and change classification tasks. Descriptions of these activities follow.

Knabb Tract Data Preprocessing

The primary preprocessing task involved the registration of two Landsat frames to a 1:24,000 scale base with property boundary information merged with the Landsat imagery. Although one of the Landsat frames (21050-14515) was available in-house, a portion of the frame

necessary for the preprocessing was destroyed during an earlier process, necessitating the reordering of the data. The second data set, Landsat frame 21482-15101 was not expected to arrive until 28 September 1979. Both Landsat frames would have to be reformatted to LARSYS Version 3.0 format and geometrically corrected (systematic removal of first order distortions) to a scale of 1:24,000 with a line printer aspect (10X:8Y).

As one of the intents of the test was to determine the timeliness of Landsat in providing land cover information, it was important to complete the preprocessing activity in minimal time. Using PERT planning, a probable completion date was estimated as 12 October 1979. This date was based upon a starting date of 1 August 1979 and receipt of the February 1979 Landsat data on 28 September 1979. Actual completion of the preprocessing task was 11 October 1979.

Map digitization was performed by St. Regis Southern Timberlands Division personnel. The original intent was to digitize a 1 inch to 1 mile map in the hope of eliminating the editing problem of digitally reconnecting the maps. However, the boundaries to be digitized were drawn on 1:24,000 scale USGS quadrangle maps. A determination was made that accuracy would be lost by transferring the boundaries to the 1 inch to 1 mile map and then rescaling the data back to 1:24,000. A decision was made to digitize the boundaries directly from the USGS 1:24,000 scale maps and join the maps together digitally. This final method worked very well with no unanticipated problems. A portion of the digitized data is shown in Figure 2.3.2 .

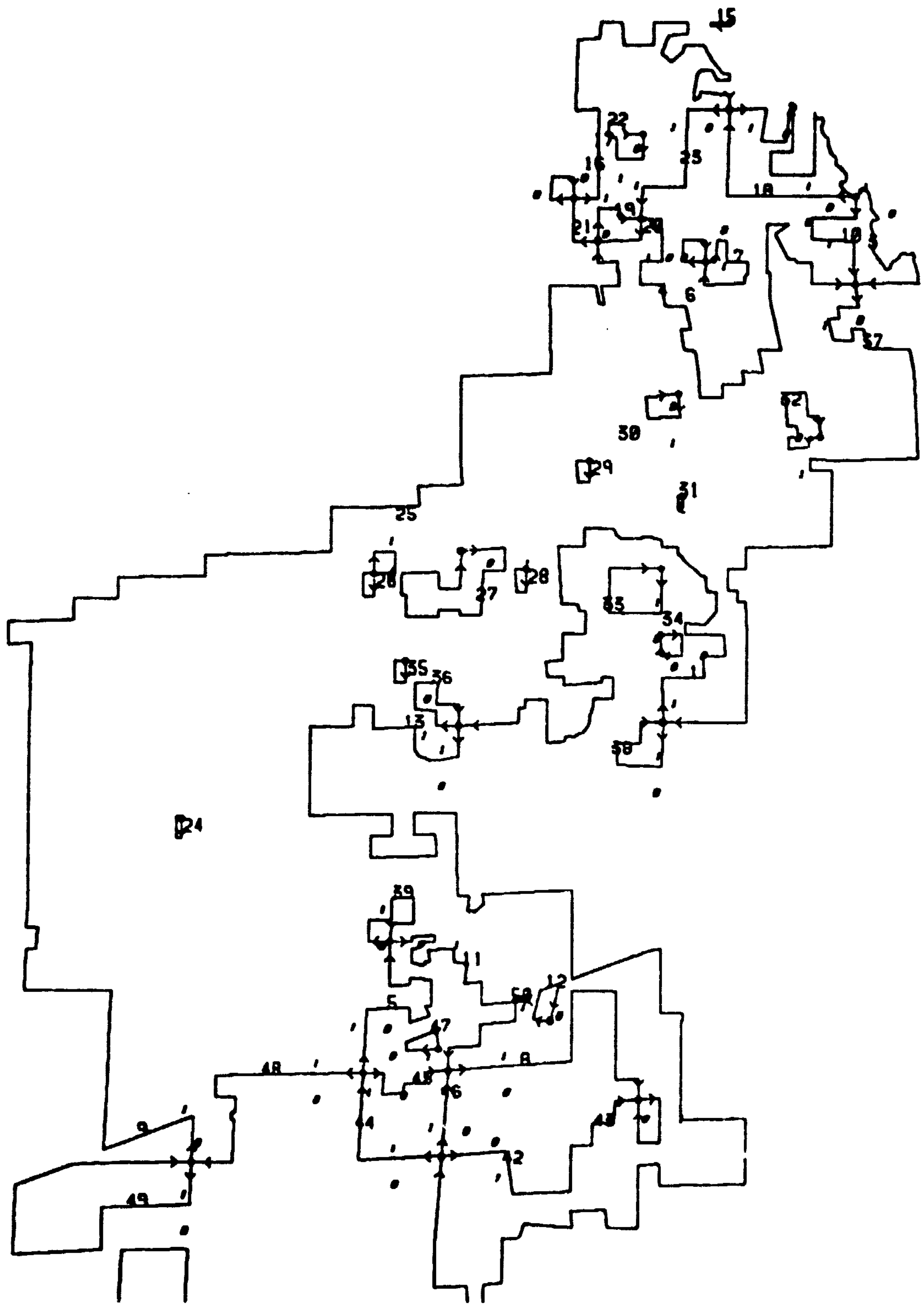

Figure 2.3.2 An example of a portion of the digitized Knabb tract map data.

At the same time the maps were being digitized and the digital boundary information edited the 7 December 1977 data was reformatted to LARSYS format and geometrically corrected. After completing the digitizing, 14 checkpoints were located between the 7 December 1977 data and the USGS quad maps using the LARSYS IMAGEDISPLAY program.

The 14 control points were run through an affine (6 parameter non-conformal) least squares fit. The resulting transformation function exhibited a line error of 0.708 (rms) and a column error of 1.032 (rms). The following first order distortions were corrected by the transformation of the systematically corrected 7 December 1977 data to the 1:24,000 USGS map coordinates:

Scale X	1.0152
Scale Y	1.0000
Rotation	0.326 degrees
Skew	0.0299 degrees

At this point, both the digitized map boundaries and the Landsat data were in the same reference coordinate system.

The next preprocessing step was to actually create the ownership information in grid form. This was accomplished by "rasterizing" the vectored digital boundary data. Some editing of an intermediate file is normally required when the boundaries to be rasterized are of regular rectangular polygons. This was the case for the Knabb tract although minimal editing of the intermediate file was required. The final result was a tape in LARSYS format containing the precision (map) registered data with an auxiliary data channel containing ownership

information. All data outside of the ownership was set to a null value (hex 00).

The second Landsat data set (21482-15101, 12 February 1979) arrived on September 28. The tape received was created in the newer EDIPS format rather than in the expected X format. The tape was reformatted using the new EDIPS to LARSYS reformatting software.

As the second data set was already corrected by NASA to eliminate radiometric and geometric distortions, it was necessary to correct only for rotation, scale, and aspect. The EDIPS corrected tapes are registered to a Mercator projection (either Hotine or Space Oblique) using ground control. The resulting scale of this data set is approximately 1:17952.7 with each pixel representing a ground resolution of 57m square. As the current geometric correction processor is designed to correct for pixel size and skew, corrections already applied to the data by the NASA process, a transformation to correct for rotation, image scale, and pixel aspect using the image registration system was developed. The method for performing this type of correction through the image registration system is described in Appendix A2.

The final step was to register the corrected second Landsat scene to the December 1977 data. A total of 185 checkpoints were located between the two images using the numerical autocorrelator of the image registration system. An average correlation coefficient of 0.69 was obtained through 270 correlation attempts between the second channel of each scene. The average error between the predicted and observed checkpoint location was 0.67 pixels. The checkpoint pairs were then

run through a biquadratic least squares fit. All control points were accepted with rms errors of 0.099 in the line direction and 0.283 in the column direction. The following first order distortions were corrected by registering the corrected EDIPS Landsat scene to the map reference grid:

Scale X	0.9999183
Scale Y	1.0006683
Rotation	-0.1515851 degrees
Skew	0.075 degrees

The Knabb Classification

The acquisition by St. Regis of the Knabb tract provided an opportunity to extend the classification procedures into an unknown area - one for which no photography or forest cover type information was available to the analyst to aid in defining a classification training set. The Knabb property is located about 50 miles southeast of the Fargo, Georgia. The Fargo test site had been classified in the first year of the project. Both areas are included in the same Landsat data faames and the forest cover types were known to be similar at both sites. Since there was interest in finding how quickly such a classification could be produced, the initial plan was to use the existing training set from the Fargo area to classify the Knabb site.

The most recent data set from these sites had been collected on December 7, 1977, although a data set collected on December 30, 1976 was also available. After examining the data it was found that in the 1976 data the Knabb site was about half obscured with clouds and most of

the remaining half was in cloud shadow. The 1977 data was cloud-free and otherwise of excellent quality. However, no single data training set was available for the 1977 data since it had been used only in a bitemporal analysis.

In order to save time the December 7, 1977 data was classified with the December 30, 1976 training set. Normally this difference in data sets would have caused serious, if not insurmountable, data calibration problems. In this case, however, the dates of data collection were both in December and were very near to the data of minimum sun angle. This, plus the fact that the weather condition were ideal over the training area in 1976 and the Knabb tract in 1977 allowed the use of the 1976 training set with 1977 data without calibration. The only significant classification problem was found to be the lack of a training class to represent the clear cut/site prepared areas which were present at the Knabb site but did not occur at Fargo. This deficiency was quickly corrected by adding two training classes generated from the Knabb 1977 data to represent these cover type conditions. A summary is shown in Table 2.3.1 .

Table 2.3.1 Area statistics for the Knabb Tract calculated from a classification of December 7, 1977 Landsat data.

Cover type	Acres	Hectares	Percent
Pine	22,723	9,200	52.2
Pine/Hardwood	10,916	4,420	25.0
Slash/Cypress	8,275	3,350	19.0
Nonstocked	1,521	616	3.5
Wet lands	122	49	0.3
	43,557	17,635	100.0

After this initial classification was completed a new data set was received. This data set, collected on February 12, 1979, was overlain onto the 1979 data. Property boundary lines were digitized and added to this data set. A separate analysis was carried out using the previous classification augmented with information gathered during the field checking as training aids. The data quality was not nearly as good as that of the two previous sets. The 0.6-0.7 micormeter band was unusable due to severe banding. The classification was done with the three remaining bands. A summary of the classifications is shown in Table 2.3.2 .

Table 2.3.2 Area statistics for the Knabb Tract calculated from a classification of February 12, 1979 Landsat data.

Cover type	Acres	Hectares	Percent
Pine	25,487	10,319	58.5
Pine/Hardwood	5,972	2,418	13.7
Slash/Cypress	10,959	4,437	25.2
Nonstocked	719	291	1.7
Wet lands	420	170	0.9
	43,557	17,635	100.0

In the two-year interval between the two data collections, several areas were cut and planted or were being prepared for planting. The two classifications were compared with the CHANGE processor to find and identify these areas and those results are shown in Table 2.3.3 . The two original classifications are shown in figures 2.3.3 and 2.3.4 and the change map is shown in figure 2.3.5 .

Table 2.3.3 Area statistics for the Knabb Tract showing changes in ground cover which occurred between the two classifications.

Change	Acres	Hectares	Percent
New Plantation	7,686	3,112	17.7
Harvested	484	196	1.1
No change	30,634	12,403	70.3
Unidentified change	4,753	1,924	10.9
	43,557	17,635	100.0

2.4 Management

The management activity oversees day to day project operations and is responsible for all technical and fiscal project reports. Status of all major System Transfer Tasks are shown in Exhibits 1 through 4 of Appendix B.

In addition to the operational project functions, special support studies, like the Knabb Applications Test (reported in section 2.3) are monitored from the task. One project that is especially noteworthy involves the application of regression analysis to Landsat MSS data to predict age of managed southern pine plantations. More precisely the ratio of the infrared to visible band responses are assumed to be affected by stand occupancy, which is reflected in crown closure. As stands mature, individual tree crowns occupy a greater proportion of the site (figure 2.4.1). The increasing crown closure affects the ratio, which in preliminary tests corresponds well to a measure of age.

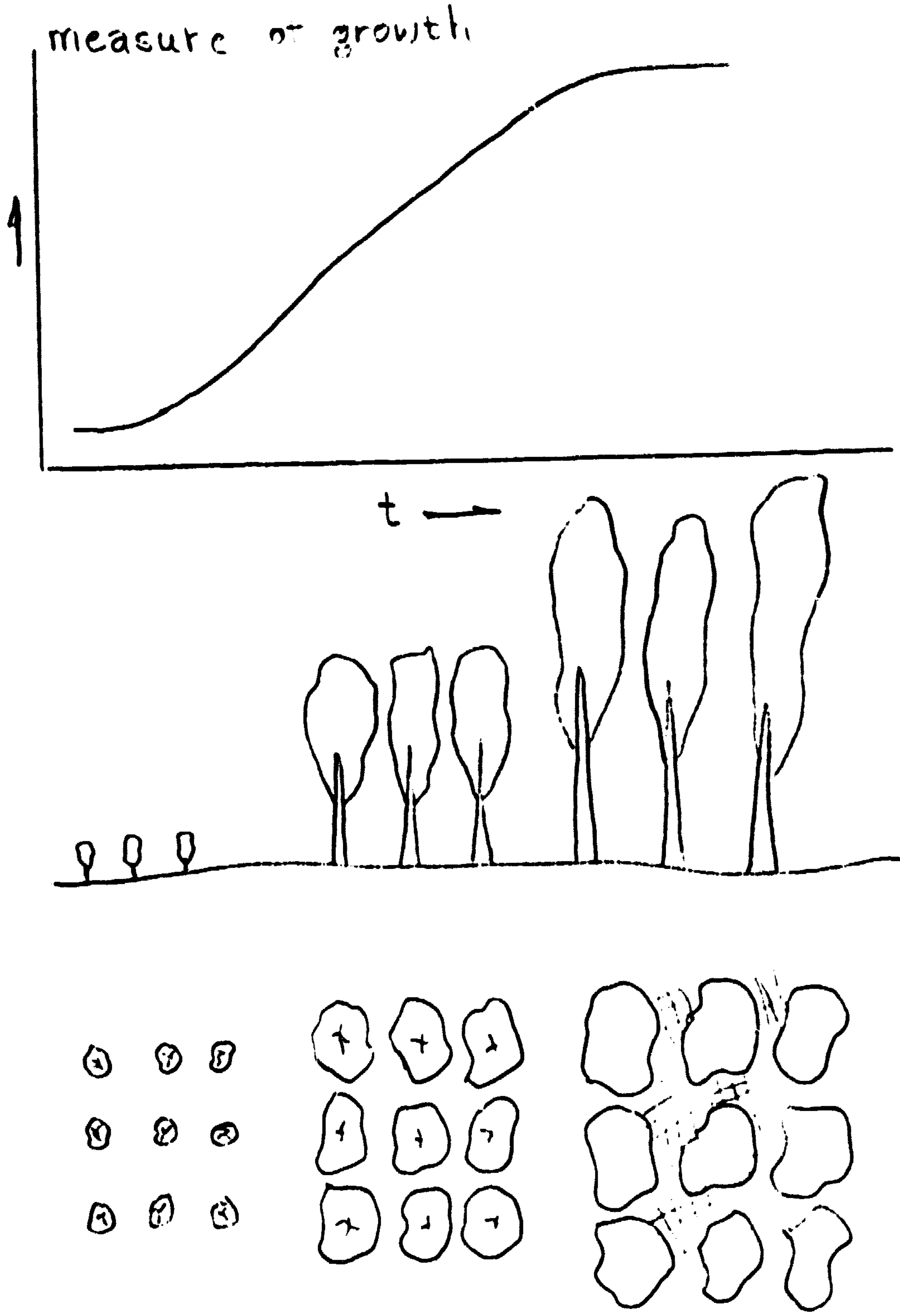

Figure 2.4.1 This is a conceptual representation of the biological growth response over time. The basic hypothesis of a ratio evaluation assumes that as a plantation matures the reflectance of the tree crowns will be the dominant factor affecting the calculated ratio. Therefore, this measure of crown closure can be related to stand age.

Knabb and Picayune Ratio Results

The ratio of IR channels to visible channels from December 1977 Landsat data for the Knabb and Picayune tracts was used to predict the age of selected pine fields. The exact ratio used, the method of picking pine fields, the analysis used to predict the fields' ages and the results of these predictions are outlined below.

The exact data ratio generated was as follows:

$$\text{ratio} = 40.0(C3 + C4)/(C1 + C2 + 0.1)$$

where

C1 = channel 1

C2 = channel 2

C3 = channel 3

C4 = channel 4

The multiplier 40.0 and the constant 0.1 were needed to enhance the range of and information in the data, and to prevent a divisor of zero.

The Knabb tract was first categorized into pine and non-pine classes. From this classfication fourteen fields of seemingly homogeneous pine were selected and the average ratio for each field was determined. Due to the proximity of this tract to the Fargo test site and their similar physiography, a regression equation developed for Fargo was used to predict the ages of the selected Knabb fields. Four of the Knabb fields were dropped from further analysis. Two of these discarded fields were accidently picked outside the Knabb boundaries and the other two dropped fields were inaccessible for checking ground truth. Of the ten pine fields left, a ground inspection of the area

established that (1) all ten fields were pine, and (2) nine of the ten fields had ages within the ninety percent confidence interval for each predicted age. Ages were derived by taking increment cores and counting growth rings of randomly selected dominant trees.

Table 2.4.1 shows the preliminary results obtained by applying the Fargo prediction equation to the ratio calculated from Landsat data over the Knabb Tract.

Table 2.4.1 Preliminary results for ten pine plantations in the Knabb Tract.

Fields #	Age Measured on site	Age Predicted from Landsat Ratio	90% CI on predicted age
1	30	19	(9.4, 37)
2	40	26	(13, 51)
3	16	24	(12, 46.7)
4	24	16	(8, 31)
6	32	12	(6, 25)
7	16	20	(10, 40)
8	14	27	(14, 54)
10	5	4	(2, 9)
13	29	19	(9.5, 38)
14	18	17	(8, 33)

Prediction Equation:

$$\log_{10}(AGE + 1) = -9.333088 + 5.567559 \log_{10} (ratio)$$

Similarly, ten pine fields were chosen from the Picayune Test Site and the predicted age of each field was determined from an equation developed specifically for the Picayune data. The age of each field was verified by ground investigation. Table 2.4.2 shows the preliminary results.

Table 2.4.2 Preliminary trials of an age prediction equation using Landsat ratio values for Picayune, Mississippi.

Field	Ground Verified Age	Age Predicted from Landsat Ratio
1	15	17
2	18	9
3	14	10
*4	26	6
5	2	3
6	14	10
7	13	18
8	0	1
*9	26	9
10	14	16

Prediction Equation:

$$\log_{10}(\mathrm{AGE} + 1) = -4.913634 + 3.218647 \log_{10} (\mathrm{ratio})$$

*both these fields had actual ages beyond the range of the regression equation. Of the ten Picayune fields checked, two (fields 4 and 9) fell outside the 90% confidence interval for the predicted age.

Another application of the generated ratio channel was a classification of the Knabb area done solely with the ratio channel (LEVELCLASSIFY). Analysis done on the Fargo test site revealed the fact that the average ratio of hardwood fields in winter data fell below the average ratio of pine fields. Hence using the ratio intervals developed on the Fargo test site, the Knabb tract was classified into hardwood, young pine (less than 15 years old), and old pine (15 years old or over).

Since the levels for the levelclassifier were determined using averages over fields, these levels did not apply directly to classifying

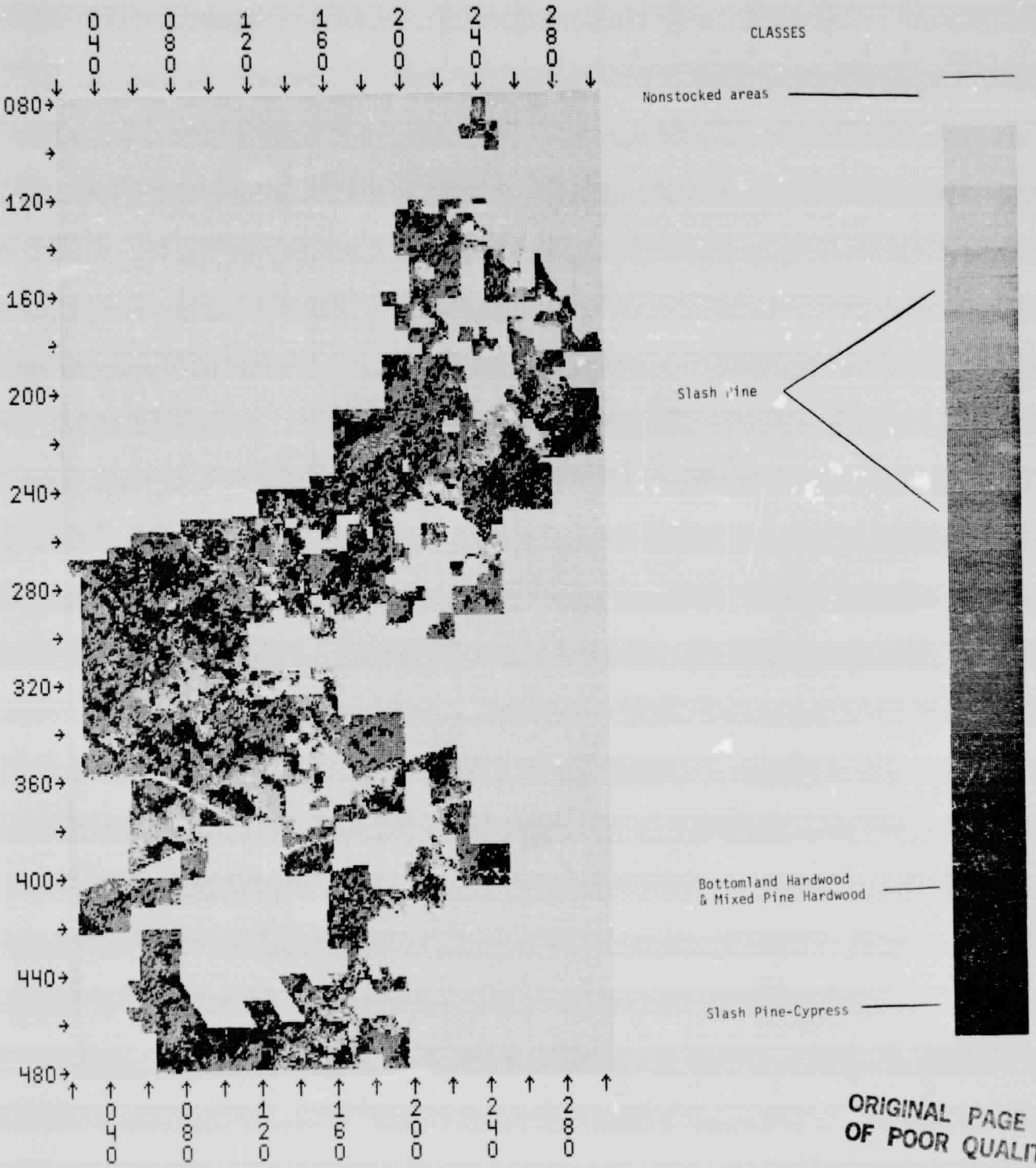

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Figure 2.3.3 Classification of December 7, 1977 Landsat data for the Knabb Tract. Area statistics for this classification appear in Table 2.3.1 .

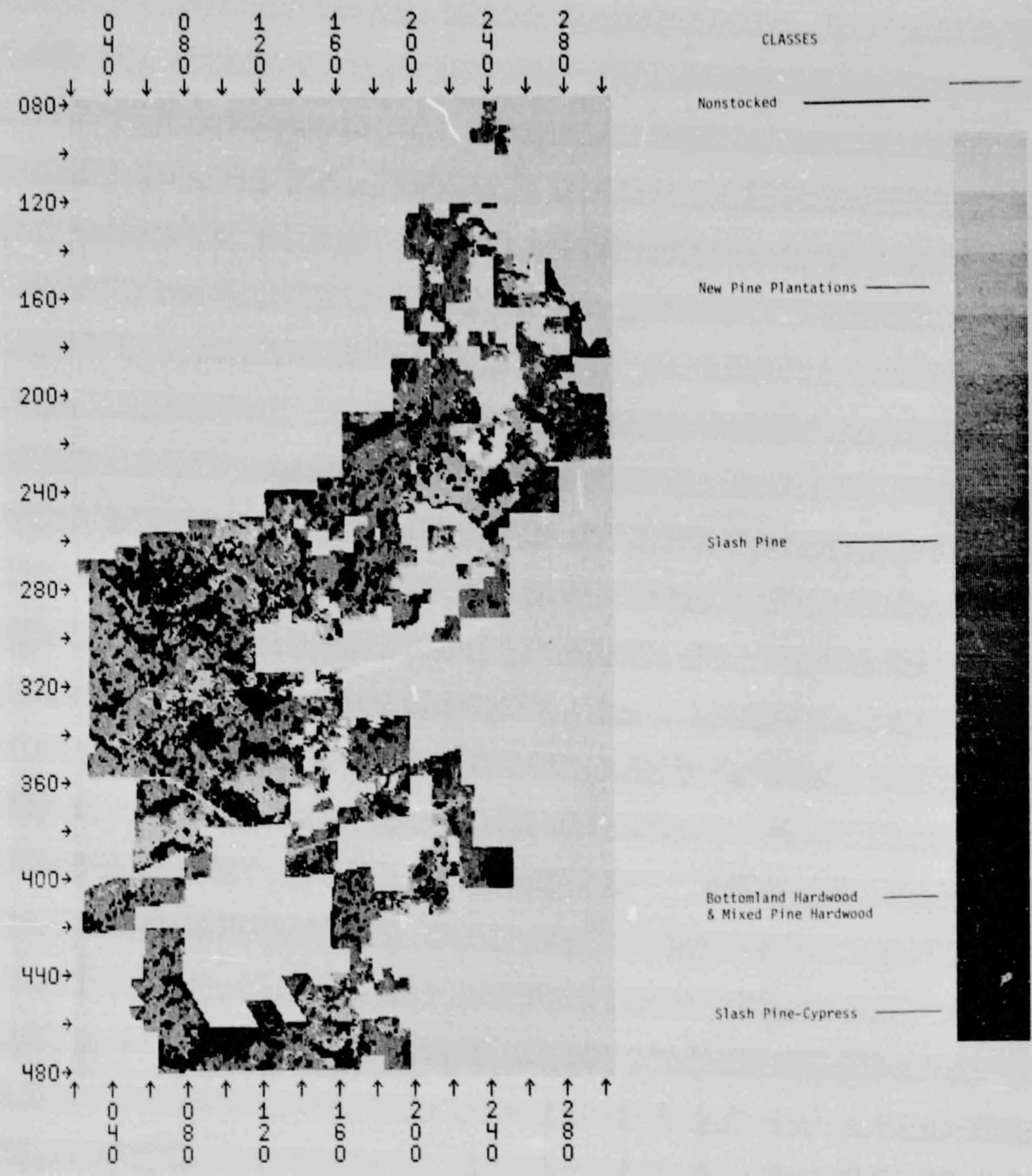

Figure 2.3.4 Classification of February 12, 1979 Landsat data for the Knabb Tract. Area statistics for this classification appear in Table 2.3.2 .

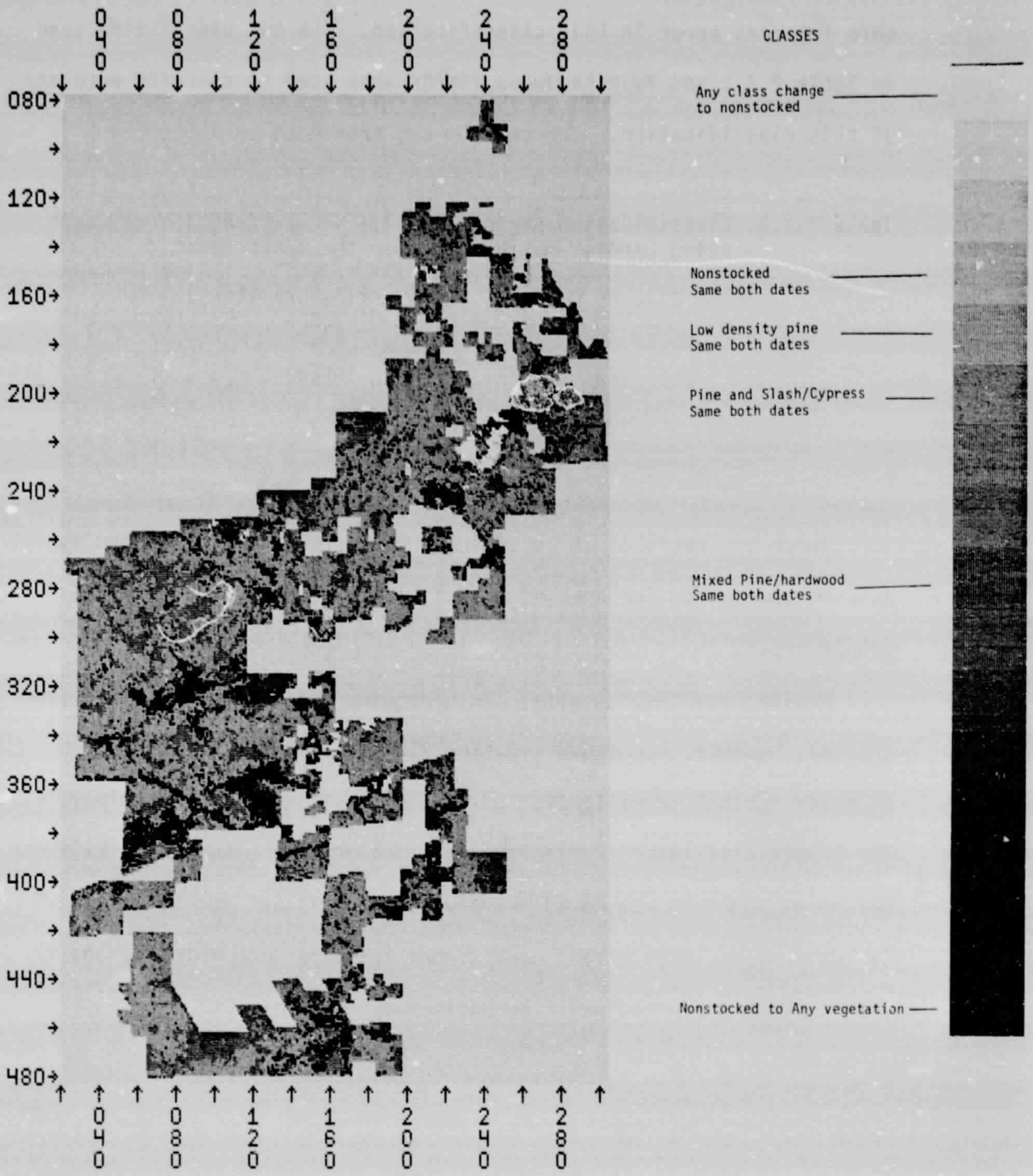

Figure 2.3.5 This is an example of a change map which shows the areas which changed between the 1977 and 1979 classifications. Area statistics for the changes shown on this map appear in Table 2.3.3 .

pixels. Also the levels were determined on another site causing even more inherent error in this classification. The ten pine fields used in Table 2.4.1 and four hardwood fields were used to test the accuracy of this classification. The results are presented in Table 2.4.2 .

Table 2.4.3 Classification performance for a LEVELCLASSIFY approach using Landsat ratio input for the Knabb Tract.

Classes	Classification accuracy
young pine	45.8
old pine	57.4
hardwood	60.0

overall accuracy = 57.4

Hence the ratio of IR to visible Landsat channels has shown usefulness in predicting the ages of pine fields even over areas with no ground truth.

Preliminary results using the generated ratio as a classification channel, however, has shown questionable usefulness. This does not preclude further investigation of levels classification technology. The levels classifier is significantly faster than a maximum likelihood per point approach and could therefore be beneficial for "first look" evaluations of large areas. Additional investigation into the application of this approach will be pursued.

APPENDIX A-1

Example of Structured English Module

Structured "English" Program

```
PROGRAM lndsup
      (* Landsat to LARSYS program *)

   DECLARATIONS
      control-cards : file;
      end-of-file   : file-condition;
      error-level, abort : error-level-indicator;
      start, stop   : time;
      dummy, clock, totcpu, vircpu : computer-usage;

 BEGIN
    CALL cptime(dummy, clock, totcpu, vircpu);
    CALL getime(start);
    REPEAT
       CALL lndint;  (* initialize *)
       CALL lndrdr;  (* read control card file *)
       IF NOT(end-of-file ON control-cards) THEN
          IF error-level < abort THEN
             CALL lndctl;  (* reformat Landsat *)
             CALL lndwup   (* wrap-up reformatting *)
          ENDIF;
          CALL lndsum   (* summarize the job *)
       ENDIF
    UNTIL end-of-file ON control-cards OR
          error-level >= abort;
    CALL usage(clock, totcpu, vircpu);  (* print computer time used *)
    CALL getime(stop);
    CALL lndf17   (* print FORM-17 *)
END
```

```
C     PROGRAM LNDSUP
C
      IMPLICIT INTEGER * 4 (A-Z)
C
C*********************************************************************
C
C LANDSAT REFORMATTING SUPERVISOR
C WRITTEN 05/23/79 BY KEN DICKMAN
C
C*********************************************************************
C
C  ROUTINES INVOKED DIRECTLY BY LNDSUP
C
C       CPTIME
C       GETIME
C       LNDCTL
C       LNDINT
C       LNDF17
C       LNDRDR
C       LNDSUP
C       LNDHLP
C       USAGE
C
C*********************************************************************
C
C   THE LANDSAT-EDIPS TO LARSYS REFORMATTING ROUTINES
C
C BINSRH = PERFORM A BINARY SEARCH
C CASCII = CONVERT ASCII CHARACTERS (BYTES) TO EBCDIC CHARACTERS
C CHAR   = ASSIGN A LITERAL CHARACTER STRING
C CONDMP = DUMP CONTENTS OF AN ARRAY WITH ADDITIONAL INFO
C CPTIME = GET VIRTUAL AND TOTAL CPU TIME USAGE
C CTLCBC = INSERT COMMAS IN THE CONTROL CARD SO CTLWRD WILL WORK
C CTLPRM = (ENTRY POINT OF CTLWRD) READ PARAMETERS FROM CONTROL CARDS
C CTLSPN = SPAN OVER COLUMNS (ALSO SO CTLWRD WILL WORK)
C CTLTAI = CONVERT CHARACTER (IN A1 FORMAT) TO INTEGER
C DARSIN = FORTRAN DOUBLE PRECISION ARC SINE
C DATAN  = FORTRAN DOUBLE PRECISION ARC TANGENT
C DCOS   = FORTRAN DOUBLE PRECISION COSINE
C EOT    = WRITE END-OF-TAPE AND MORE
C ERRPTR = PRINT A DOLLAR SIGN BENEATH THE ERROR IN THE CONTROL CARD
C FILSRH = FIND THE FIRST OCCURANCE OF AN EMPTY FILE ON A TAPE
C GEBYTE = COMPARE THE BYTES FOR GREATER THAN OR EQUAL TO
C GETIME = GET TIME OF DAY
C GTDATE = GET DATE
C GTUNIT = (ENTRY POINT OF TAPOP) FIND THE DEVICE ADDRESS OF A TAPE
C IDHTIE = CHECK LARSYS HEADER RECORD AND MORE
C IVAL   = (ENTRY POINT OF RDDVAL) READ VALUES ON CONTROL CARDS
C JTOR   = CONVERT A JULIAN DATE TO ROMAN (IE. MONTH, DAY, YEAR)
C LNDANC = PROCESS THE LANDSAT ANCILLARY RECORD
C LNDANN = PROCESS THE LANDSAT ANNOTATION RECORD
C LNDARC = WRITE TO ARCHIVE TAPE
C LNDBIL = OUTPUT PROCESS FOR BIL FORMAT
C LNDBSQ = OUTPUT PROCESS FOR BSQ FORMAT                            *
C LNDCAL = CALCULATE LINE CORRECTIONS                               *
C LNDCCL = CHECK THE COLUMNS SPECIFIED
C LNDCOR = PERFORM LINE CORRECTIONS                                 *
C LNDCTL = CONTROL ACCORDING TO THE LANDSAT INPUT TAPE STRUCTURE
C LNDDIR = PROCESS THE LANDSAT DIRECTORY RECORD
C LNDERR = RECORDS ERRORS + COUNTERED
C LNDF17 = GENERATE RUN COMPLETION FORMS  (EG. FORM117)
C LNDHED = PROCESS THE LANDSAT HEADER RECORD
C LNDIMA = PROCESS THE LANDSAT IMAGE RECORD
C LNDINT = INITIALIZE VALUES
C LNDLID = CREATE LARSYS ID RECORD FROM LANDSAT-EDIPS DIR & HED RECORDS
C LNDMIL = MERGE AND RETAIN BIL BANDS FOR A LINE
C LNDMSQ = MERGE BSQ BANDS FOR A LINE                               *
C LNDNEG = CONVERT LIGHT BOARDER PIXELS TO DARK BOARDER PIXELS
C LNDPAG = PRINT A HEADER AT THE TOP OF THE OUTPUT PAGE
C LNDPAN = PUNCH ANCILLARY DATA FOR FUTURE LANDSAT CORRECTIONS      *
C LNDPRM = READ CONTROL PARAMETERS ON CONTROL CARDS
C LNDRES = RE-START TO GET SUMMARY OF EXECUTION (HELP DEBUGGING)
C LNDRDR = CONTROL CARD READER
C LNDSET = CREATE LARSYS ID, DECIDE MERGES, WRITE UNITS (FOR BSQ)   *
C LNDSUM = PRINTS INFO FOR THE JOB MOST RECENTLY RUN
C LNDSUP = LANDSAT REFORMATTING SUPERVISOR
C LNDTRA = PROCESS THE LANDSAT TRAILER RECORD                       *
C LNDVAL = READ CONTROL PARAMETER VALUES ON CONTROL CARDS
C LNDWRT = WRITE LINE IMAGE IN LARSYS FORMAT
```

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```
C [illegible] : WRAP-UP LANDSAT REFORMATTING
C [illegible] : MOUNT A TAPE ON A TAPE DRIVE
C [illegible] : COPY BYTES
C [illegible] : (ENTRY POINT OF TAPOP) CHECK THE WRITE PROTECT RING
C [illegible] : GET A DELIMITED STRING FROM AN ARRAY IN A4 FORMAT
C [illegible] : (ENTRY POINT OF TAPOP) WRITE AN END-OF-FILE TO TAPE
C [illegible] : (ENTRY POINT OF TAPOP) FORWARD FILE A TAPE
C [illegible] : (ENTRY POINT OF TAPOP) READ A RECORD FROM TAPE
C [illegible] : (ENTRY POINT OF TAPOP) REWIND AND UNLOAD A TAPE
C [illegible] : (ENTRY POINT OF TAPOP) WRITE A RECORD TO TAPE
C [illegible] : PRINT JOB INFO SUCH AS CONNECT, VIRTUAL, AND TOTAL CP TIME
C [illegible] : CALL MOUNT WITH ADDITIONAL INFORMATION
C
C *       * DENOTES THAT THIS SUBROUTINE HAS NOT BEEN FORMALLY CODED
C
C****************************************************************
C
C   BEGIN GLOBAL VARIABLES DEFINITION      (UPDATED 12/05/79)
C
      COMMON /UTLCOM/
C          ERROR CONTROL...
     1          ABCNT, ERRCNT, SEVRTY,
C
C          LOGICAL FILE UNITS...
     2          MAAUNT, PRINTR, READER, TTYIN, TTYOUT, UNIT(4),
C
C          FREQUENTLY USED LITERAL STRINGS...
     3          ABLANK, EBLANK, MSS, RBV, RI, RC
C----------------------------------------------------------------
C     VARIABLES SET BY THE CONTROL CARD READER
C     TO AFFECT THE REFORMATTING OPERATION
      COMMON /REFCTL/
C          COMMENTS...
     1          COMMNT(20,2), NOCOMM,
C
C          CONTROL CARDS...
     2          ECFROR,
C
C          INPUT TAPE...
     3          INDEN, INDET, INMNT, INTAPE(3), TAPNDX, TOTTAP,
C
C          INPUT TAPE REFORMATTING...
     4          BILSCN, COLUMN(3), LINES(3), MAINCH, NOCHAN, USECHN,
     4          USECOL, USELIN,
C
C          OUTPUT TAPE...
     5          FLIGHT(16), MXOUCH, OUFILE, OUTAPE, OUIDEN, OUTDET,
     5          OUTMNT, RUN, USEFLT, USEOUT,
C
C          ARCHIVE TAPE...
     6          ARCDET, ARCMNT, ARFILE, ARTAPE, USEARC, USEARF,
C
C          SCRATCH TAPE...
     7          SCRDET, SCRMNT, SCRNDX, SCRTAP(2), TOTSCR, USESCR,
C
C          MISCELLANEOUS...
     8          PATCH(4)
C
      LOGICAL * 4 ARCDET, ARCMNT, ECFROR, INDET, INMNT, OUTDET,
     $      OUTMNT, SCRDET, SCRMNT, USEARC, USEARF,
     $      USECHN(30), USECOL(3), USEFLT, USELIN(3),
     $      USEOUT, USESCR
C----------------------------------------------------------------
C     USING THE INPUT STRUCTURE TO DETERMINE PROCESSING
      COMMON /CTLCOM/
C          THE INPUT STRUCTURE...
     1          NS, PS, PSNS(16,16), RECTYP(6,3), STATES(16),
C
C          THE INPUT FREQUENCY...
     2          COUNT(16), FREQ(16,16),
C
C          SETTING UP THE REFORMATTING...
     3          DONE, MAXRC, MERFLG, ROSCR(1), SELECT, WRUNIT
C
      LOGICAL *4 DONE, MERFLG
C----------------------------------------------------------------
C     BUFFER VARIABLES
      COMMON /BUFCOM/
C          INPUT BUFFER VARIABLES...
```

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```
     1          INCHR, INCNT, INLIN, INREC(1347), NRICNT,
C
C         SCRATCH BUFFER VARIABLES...
     2          PASSCR, PRSCNT, SCRCAT(1), SCRREC(8006),
C
C         LANSYS OUTPUT TO HEADER RECORD...
     3          LANSIC(200),
C
C         FLSM - IIC...
     4          FIT(256), FURMS, NUFCRM
C---------------------------------------------------------------------
C      OUTPUT VARIABLES
       COMMON /OUTCOM/
C         GENERAL...
     1          FLUSH, PROCNT, OUICHR, OUTCNT, OUTLIN,
     .          OUTREC(8806), RECCNT, ROLL,
C         CONVERTING LIGHT BOARDER PIXELS TO DARK...
     2          FIRCOL(30), LEF, LSTCOL(30), RIT, TOTMAX(4)
C
       LOGICAL * 4 FLUSH
       INTEGER *2 RECCNT, ROLL
C---------------------------------------------------------------------
       COMMON /JOBCOM/ CLOCK(3), CURENT(3),
     $        DATE(3), DUMMY(2), LADVER, START(3), TOTCPU(2),
     $        UPDATE(2), USERID(2), USERNA(4), VIRCPL(2),
     $        WRTAPE
C
       REAL *4 LADVER
C---------------------------------------------------------------------
C      BEGIN LANDSAT-EDIPS RECORDS' GLOBAL VARIABLES
C
          COMMON /DIRCOM/ CCTVOL, DAYGEN, DIRDMP, DIRID(3), DLEVTY,
     1           DSCENE(13), DWRS(2), MONGEN, NUMVOL, VERDOC, VERSCF,
     2           YRGEN
          LOGICAL *4 DIRDMP
C
          COMMON /HEDCOM/ ACTSTA(2), ATMSCA, CONENH, EDGENH, GCAPPL,
     1           GCPRES, HCALWD, HIDDMP, HLEVTY, HRESMP, HSCENE(3),
     2           HSENTY, HWRS(2), IMAID(3), MAPAPP, PIXLN1, PIXLN2,
     3           QUALAS, RCAPPL, RCPRES, TIMERP(4), IMPREG
          LOGICAL *4 HEDDMP
          INTEGER * 2 IMPREG(10)
C
          COMMON /ANNCOM/ ANNDMP, EPHMRS, FRMCEN(4), LATLON(4), NAFSPP,
     1           PROJ, SCALE, SCNANG(4), TYPCOR
          LOGICAL * 4 ANNDMP
C
          COMMON /IMACOM/ IMADMP, LFILL, RFILL, SCNCNT
          LOGICAL *4 IMADMP
C
          COMMON /CPMAID/ FIL, MSG, NO, YES
C
C       END LANDSAT-EDIPS RECORDS' GLOBAL VARIABLES
C
C  END GLOBAL VARIABLES DEFINITION
C
C**********************************************************************
C
C  LOCAL VARIABLES DEFINITION
C
        INTEGER * 4 STOP(3)
C
C**********************************************************************
C
C  LOCAL VARIABLES DESCRIPTION
C
C STOP    = ENDING TIME FOR THIS JOB SET
C
C**********************************************************************
C
       CALL CPTIME(DUMMY, CLOCK, TOTCPU, VIRCPL)
       CALL GETIME(START)
C
C      PRINTR & TTYOUT ARE ALSO INITIALIZED IN LNDINI
       PRINTR = 6
       TTYOUT = 16
C
       WRITE (PRINTR, 9100) START
       WRITE (TTYOUT, 9100) START
```

```
 910  FORMAT(' IC001 LANDSAT REFORMATTING BEGINS ', 3A4,
     1   4X, '(LNDSUP)')
C
C     REPEAT PROCESSING UNTIL (END-OF-FILE(READER) OR ABORT)
 110  CONTINUE
C
C          INITIALIZE COMMON BLOCKS
           CALL LNDINT
           IF (SEVRTY .GE. ABORT) GOTO 290
C
C             READ CONTROL CARDS
              CALL LNDRCR
              IF (SEVRTY .GE. ABORT) GOTO 260
                 IF (ECFRCR) GOTO 230
C
C                   CONVERT LANDSAT TO LARSYS
                    CALL LNDCTL
C
C                      WRAP-UP CONVERSION FROM LANDSAT TO LARSYS
                       CALL LNDWUP
                       IF (SEVRTY .GE. ABORT) GOTO 170
                          WRITE (PRINTR, 914C)
                          WRITE (TTYCUT, 914C)
 914C                     FORMAT(///, ' IC002 LANDSAT TO LARSYS COMPLETE',
     1                        4X, '(LNDSUP)')
 170                   CONTINUE
                       ENDIF
C
 230                CONTINUE
                    ENDIF
C
 260          CONTINUE
              ENDIF
C
 290       CONTINUE
           ENDIF
C
C
           IF (ECFRCR) GOTO 720
C
C             WRAP-UP SUMMARY FOR ONE CONTROL CARD SET
C
              CALL LNDSUM
 720       CONTINUE
           ENDIF
C
C     UNTIL (ECF(READER) OR ABORT)
      IF (.NOT. ECFRCR .AND. SEVRTY .LT. ABORT) GOTO 110
C
C*******************************************************************
C WRAP-UP SUMMARY FOR ALL CONTROL CARDS
C*******************************************************************
C
C     PRINT VIRTUAL AND TOTAL CPU USAGE FOR ALL JOBS
      CALL USAGE(CLOCK, TOTCPU, VIRCPU)
C
      CALL GETIME(STOP)
      WRITE (PRINTR, 9991) STOP
 9991 FORMAT(12(/), ' IC003 EXECUTION STOPS ', 3A4, 4X, '(LNDSUP)')
      WRITE (TTYCUT, 9992) STOP
 9992 FORMAT(/, ' IC004 EXECUTION STOPS ', 3A4, 4X, '(LNDSUP)')
C
C*******************************************************************
C PRINT FORM I/C
C*******************************************************************
C
      CALL LNDFIT
C
      STOP
      END
```

APPENDIX A-2

Instructions to Correct EDIPS Corrected Data Using the LARS Image Registration System

Instructions to Convert Linear Parameters to 4-Parameter Non-Conformal Transformation for use by the LARS Image Registration System.

(This algorithm is for use with Landsat-EDIPS formatted geometrically corrected tapes).

1. Set up the distortion matrix $\underline{M}$ such that

$$\underline{M} = \underline{M}_1\underline{M}_2\underline{M}_3\underline{M}_4\underline{M}_5$$

where

$$\underline{M}_1 = \begin{bmatrix} 1.0 & 0.0 \\ 0.0 & 1.0 \end{bmatrix}$$

for pixel scale (assumes 57m pixel)

$$\underline{M}_2 = \begin{bmatrix} \cos\Theta & \sin\Theta \\ -\sin\Theta & \cos\Theta \end{bmatrix}$$

for rotation, where Θ is the rotation required to a north-south orientation.

$$\Theta = \sin^{-1}\left(\frac{\cos(80.985)}{\cos\phi}\right)$$

where ϕ is run center latitude

$$\underline{M}_3 = \begin{bmatrix} 1.0 & 0.0 \\ 1.0 & 0.0 \end{bmatrix}$$

for skew (already corrected by EDIPS)

$$\underline{M}_4 = \begin{bmatrix} 0.8 & 0.0 \\ 0.0 & 1.0 \end{bmatrix}$$

for a line printer aspect of 8 lines per inch, 10 columns per inch

$$\underline{M}_5 = \begin{bmatrix} 1.3368421 & 0.0 \\ 0.0 & 1.3368421 \end{bmatrix}$$

for scale correction to 1:24000 from a scale of 1:17952.7

$$\underline{M} = \begin{bmatrix} 1.0694737 \cos\theta & 1.3368421 \sin\theta \\ -1.0694737 \sin\theta & 1.3368421 \cos\theta \end{bmatrix}$$

This distortion matrix is set up for the transformation

$$\underline{Y} = \underline{M}\ \underline{X}$$

where $\underline{X}$ is the original coordinates and
$\underline{Y}$ is the new coordinate matrix.

2. To put this into a form suitable for the registration equation:

$$\underline{Y} = \underline{X} + \underline{\Delta}$$

we must use the form

$$Y = \underline{A}\ \underline{X}$$

Expanding: $\underline{Y} = \underline{A}\ \underline{X} = \underline{X} + \underline{\Delta}$

or $Y_1 = a_{11}x_1 + a_{12}x_2 = ax_1 + bx_2 + c + x_1$

$Y_2 = a_{21}x_1 + a_{22}x_2 = dx_1 + ex_2 + f + x_2$

let $c = f = 0$,

$$a_{11}x_1 + a_{12}x_2 = (a + 1)x_1 + bx_2$$

$$a_{21}x_1 + a_{22}x_2 = dx_1 + (e + 1)x_2$$

$$a_{11} = a + 1$$

or, $a_{12} = b$ or, $\underline{A} = \begin{bmatrix} a + 1 & b \\ d & e + 1 \end{bmatrix}$

$$a_{21} = d$$

$$a_{22} = e + 1$$

3. To convert $\underline{A}$ in terms of overlay line (CLD) and column (CJD) coefficients of the image registration system, it is only necessary to observe

$$a = CJD3 = 1.0694737 \cos \Theta - 1$$
$$b = CJD2 = 1.3368421 \sin$$
$$d = CLD3 = -1.0694737 \sin$$
$$e = CLD2 = 1.3368421 \cos \Theta - 1$$

IMAGE REGISTRATION PERFORMANCE REPORT

WP= 556-PR

DATE: 9/25/79 REFORMATTER: Smith

MACT= 796

CPU=

INPUT

RUN A 77010200 LINES 1,600 COLS 75,435 CHAN -
RUN B 77010201 LINES 1,750 COLS500,1100CHAN All
BUFFER USED:

OUTPUT

RUN 77010202 TAPE 2668 FILE 2
INTERPOLATION: NN

DATA TRANSFORMATION INFORMATION

TRANSFORMATION: FORWARD BACKWARD ORDER 1

LINE RMS : 0.70806

COL RMS : 1.03212

N : 14

DISTRIBUTION R: 0.99

Registered to USGS Quad Maps

CORRELATION NA

RATE OF ACCEPTANCE ACCEPT______ REJECT______ RATE______

AVERAGE RHO :

AVERAGE EUCLIDEAN ERROR :

TRANSFORMATION COEFFICIENTS:

	LINE COEF.		COL COEF.
1:	32.494452	1:	543.055448
2:	0.015229	2:	-0.005780
3:	0.005092	3:	-0.013307
4:		4:	
5:		5:	
6:		6:	

THE FOLLOWING FIRST ORDER DISTORTIONS WERE CORRECTED:

SCALE X: 1.0152 Y: 1.0000

ROTATION 0.326 (DEGREES)

SKEW: 0.0299 (DEGREES)

IMAGE REGISTRATION PERFORMANCE REPORT

WP= 572-GC

DATE: 10/5/79 REFORMATTER: Smith

MACT= 796

CPU=

INPUT

RUN A 79000300 LINES 762,1500 COLS 1200,1698 CHAN none
RUN B 79000200 LINES 600,1700 COLS 1000,2150 CHAN 1-4
BUFFER USED: 1,500,000

OUTPUT

RUN 79000201 TAPE 2836 FILE 1
INTERPOLATION:

DATA TRANSFORMATION INFORMATION

TRANSFORMATION: FORWARD BACKWARD ORDER 1

LINE RMS :

COL RMS : NA: systematic distortions corrected for rotation, scale, aspect only

N :

DISTRIBUTION R:

CORRELATION NA

RATE OF ACCEPTANCE ACCEPT____ REJECT____ RATE____

AVERAGE RHO :

AVERAGE EUCLIDEAN ERROR : NA

TRANSFORMATION COEFFICIENTS:

LINE COEF. 1:	0.0	COL COEF. 1:	0.0
2:	0.314711	2:	0.2422435
3:	-0.1937948	3:	0.0517688
4:		4:	
5:		5:	
6:		6:	

THE FOLLOWING FIRST ORDER DISTORTIONS WERE CORRECTED:

SCALE X: 1.3368421 1:24000 LP Y: 1.0694737 1:24000 LP

ROTATION $10^{\circ}.44$ (DEGREES)

SKEW: $0^{\circ}.0$ (DEGREES)

IMAGE REGISTRATION PERFORMANCE REPORT

WP= 583-IR

DATE: 10/11/79 REFORMATTER: Smith

MACT= 796

CPU=

INPUT

RUN A 77010202 LINES 1,600 COLS 1,428 CHAN 1-4
RUN B 79000201 LINES 1,739 COLS 1,504 CHAN 1-4
BUFFER USED: 7246 bytes

OUTPUT

RUN 79000202 TAPE 2848 FILE 1
INTERPOLATION: NN

DATA TRANSFORMATION INFORMATION

TRANSFORMATION: FORWARD BACKWARD ORDER 2

LINE RMS : 0.099

COL RMS : 0.283

N : 185

DISTRIBUTION R: NA distribution appears excellent

CORRELATION

RATE OF ACCEPTANCE ACCEPT 185 REJECT 85 RATE

AVERAGE RHO : 0.69

AVERAGE EUCLIDEAN ERROR : 0.67

TRANSFORMATION COEFFICIENTS:

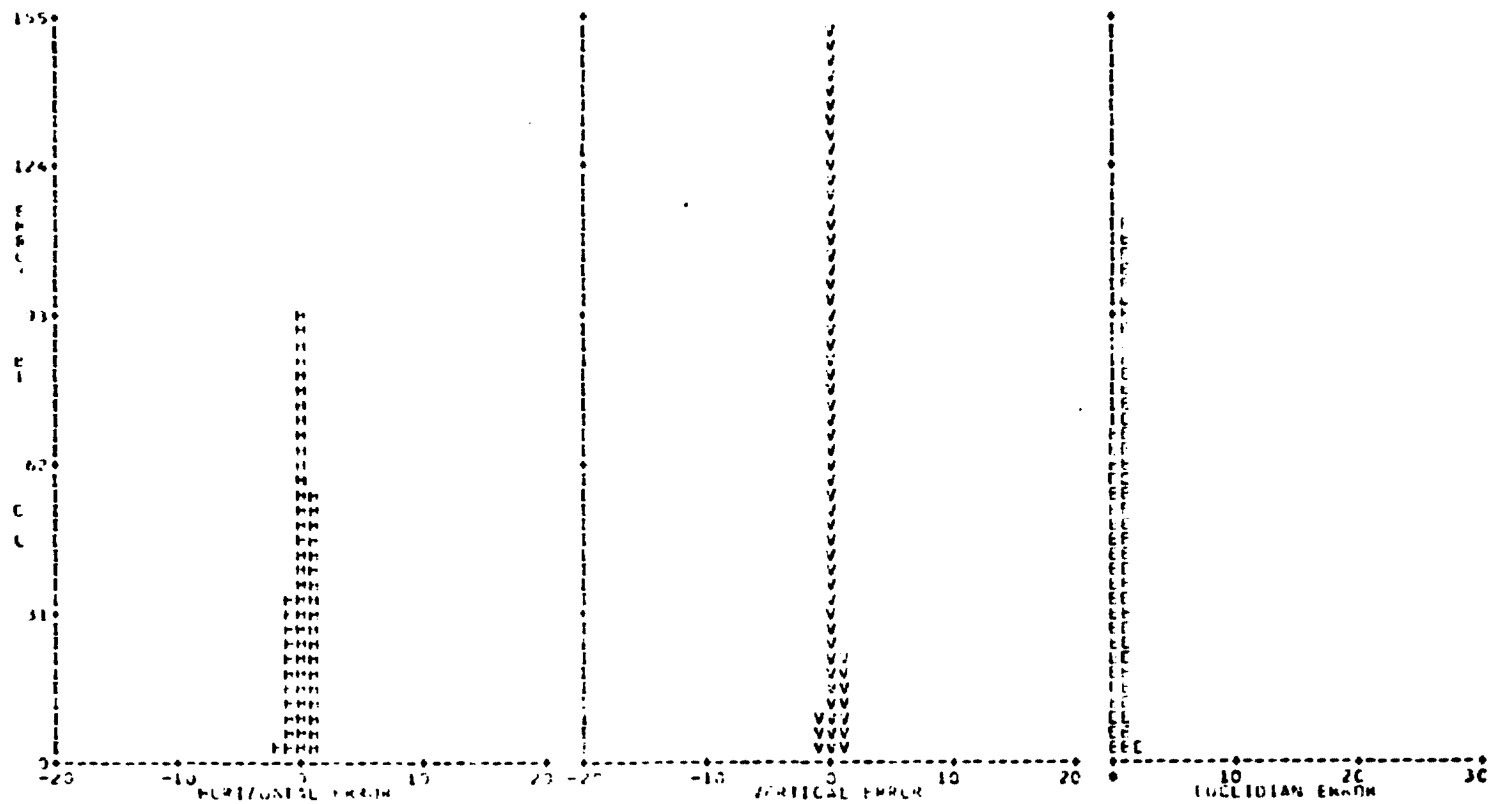
LINE COEF. 1:	129.20298180	COL COEF. 1:	66.39532730
2:	-0.00008529	2:	0.00264544
3:	-0.00133339	3:	0.00066831
4:	-0.00000039	4:	-0.00000293
5:	0.00000173	5:	-0.00000105
6:	0.00000115	6:	0.00000014

THE FOLLOWING FIRST ORDER DISTORTIONS WERE CORRECTED:

SCALE	X: 0.9999183	Y:	1.0006683
ROTATION	-0.1515851	(DEGREES)	
SKEW:	0.075	(DEGREES)	

RMS PEAK CORRELATION VALUE....... = 0.7[illegible] AVERAGE PEAK CORRELATION VALUE = 0.69
NUMBER OF ACCEPTABLE CORRELATIONS = 14[illegible] NUMBER OF REJECTED CORRELATIONS = 85
CORRELATION WINDOW = 32 BY 32 SQUARE CORRELATION DELTA............... = 4

****** HISTOGRAMS OF CORRELATION DISTANCE ERRORS ******



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Appendix B

The Exhibits that appear in this Appendix are updated versions of the milestone and timeline charts that were published in the first Phase III quarterly report. The Exhibit numbers to the following Phase III task activities:

1. Technology Transfer
2. LARSYS Transfer
3. Preprocessing Transfer
4. Management

Exhibit 1

FRIS III Timeline Chart

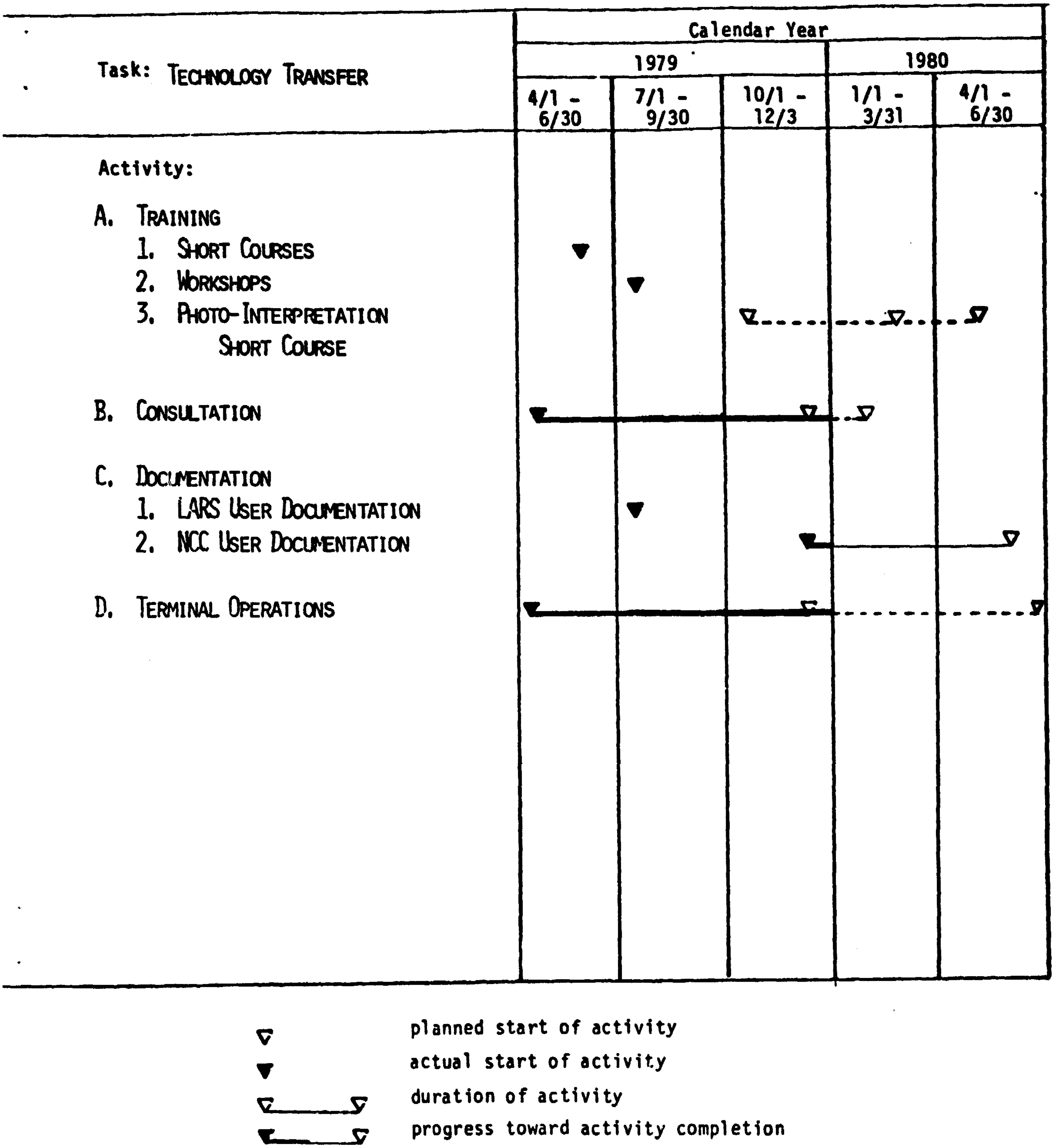
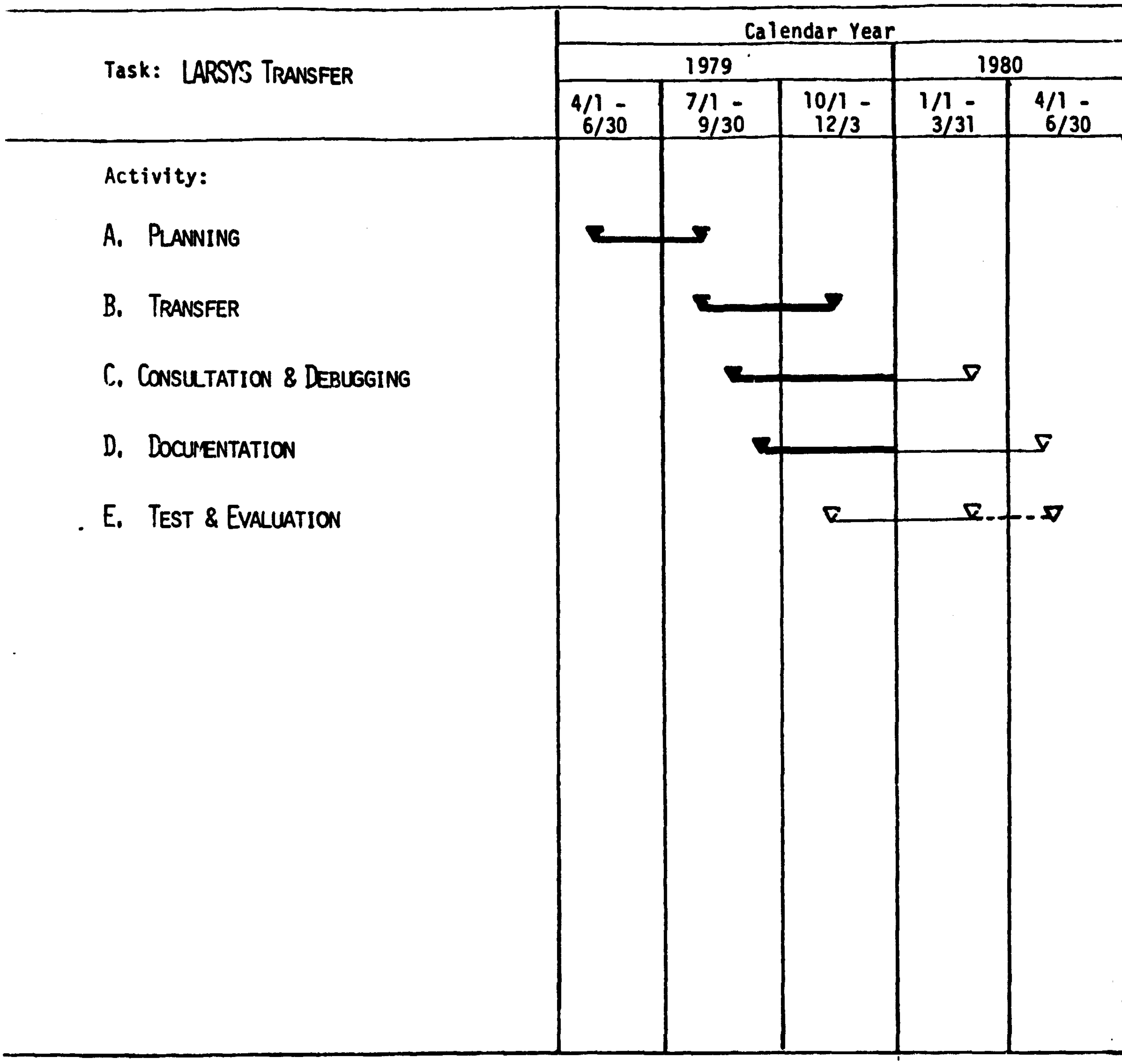


Exhibit 2

FRIS III Timeline Chart



planned start of activity

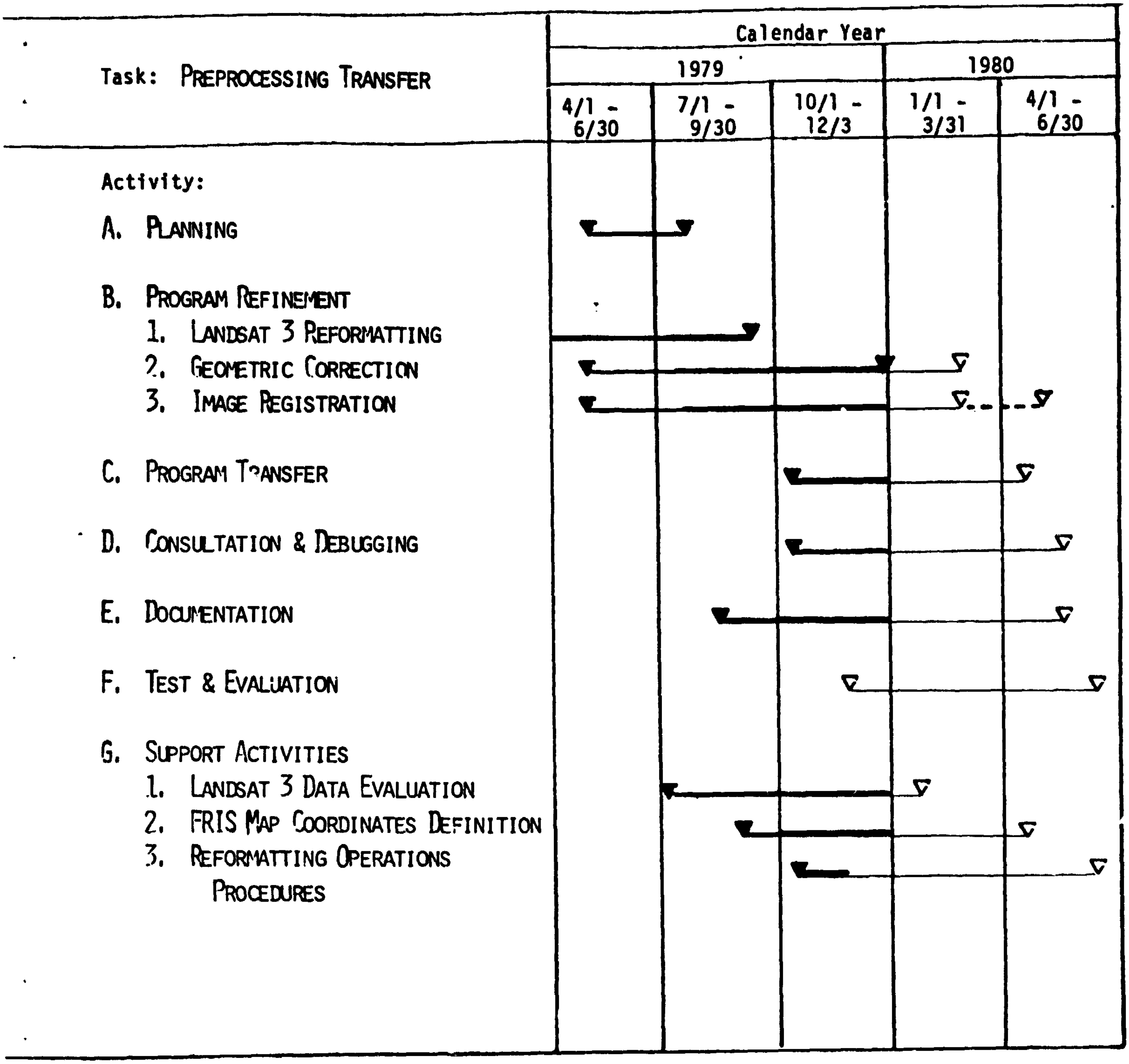
actual start of activity

duration of activity

progress toward activity completion

Exhibit 3

FRIS III Timeline Chart



planned start of activity

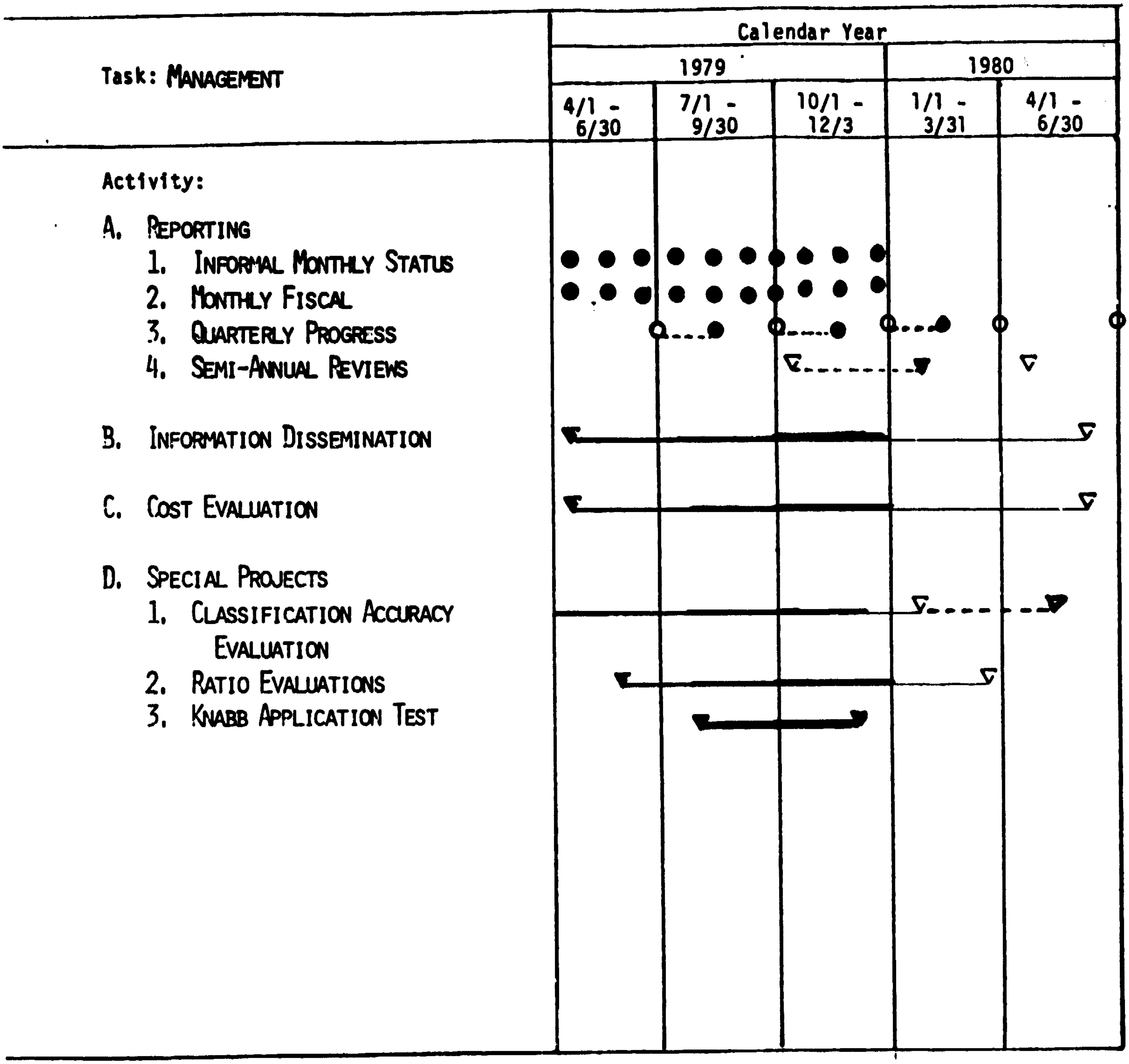
actual start of activity

duration of activity

progress toward activity completion

Exhibit 4

FRIS III Timeline Chart



planned start of activity

actual start of activity

duration of activity

progress toward activity completion